Parachute Vision Zero

Case Study Series

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Do Collision Avoidance Systems Make our Roads Safer?

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Do Collision Avoidance Systems Make our Roads Safer?

Parachute Vision Zero Network has launched a series called **Word on the Street***; one of the elements of the series is a quarterly Case Study that will feature a variety of issues and examples of Vision Zero from across Canada and around the world. We hope that these practical, evidence based case studies will help educate, inform and inspire those who are interested in getting to zero.*

What's in this issue?

Safe vehicles are a fundamental aspect of the safe systems approach. Vehicles that are designed well with the appropriate safety technologies can either prevent a crash or reduce or absorb some of the crash forces to help decrease the risk of death and serious injuries.

Not all cars are created equal and some are safer than others, but if every vehicle can be upgraded to the safest in its class, road trauma could be reduced by a third.[1] Vision Zero is committed to introducing safer car designs and technologies that have been scientifically proven to improve road safety. This case study will analyze four collision avoidance systems: lane departure warnings, forward collision warning and braking, advanced forward lighting, and blind spot detection. The analysis will discuss the safety benefits and risks of each system, the limitations of current research and the future of technology in motor vehicles.

Collision Avoidance Systems

Collision avoidance systems in motor vehicles are intended to enhance road safety by monitoring vehicle surroundings, warning drivers of upcoming obstacles and improving compliance with the rules of the road (e.g. speed limits).[2] These systems have the potential to provide added protection for vulnerable road users and are well positioned to address leading causes of collisions (e.g., distracted driving, speeding) by alerting drivers of unsafe behaviours.

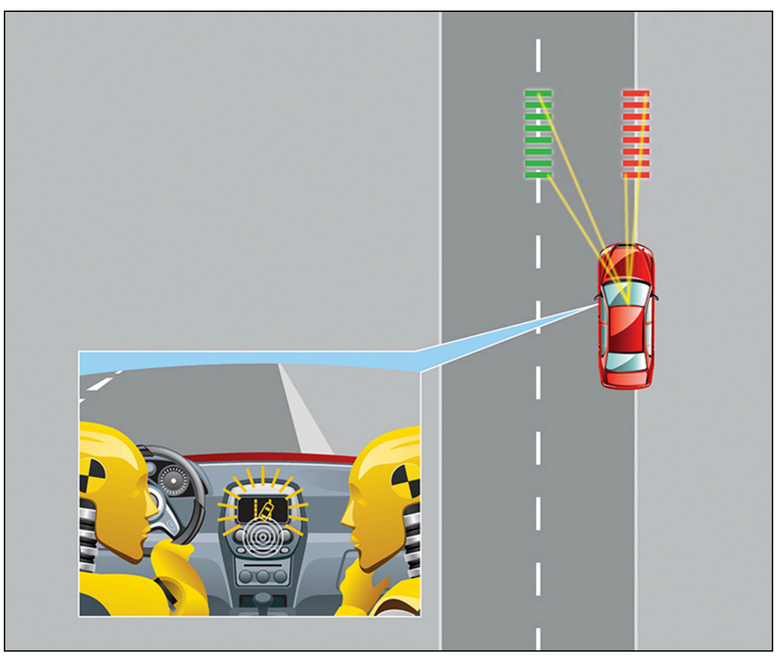
Four of the most common collision avoidance systems currently on the market are: lane departure warnings, forward collision warning and braking, advanced forward lighting, and blind spot detection.[3] It is estimated that the collective implementation of these systems could prevent or mitigate up to 1,866,000 collisions each year, including 149,000 serious/ moderate-injury collisions and 10,238 fatal collisions in the United States alone.[4]

If forward collision warning were extended to detect objects, pedestrians, and bicyclists, they could help prevent an additional 3,868 fatal crashes.

Lane Departure Warning Systems

Lane departure warning systems notify drivers when they have unintentionally left their lane without signalling. The system uses a forward-facing camera behind the rear-view mirror that detects lane markings on the road.[5]

This can help prevent various types of collisions including, single-vehicle collisions, head-on collisions (where the vehicle drifts into oncoming traffic lanes) and sideswipe collisions.[5]



Source: Transport Canada, Lane Departure Warning, 2017

TABLE 1: Lane Departure Warning Systems

Safety **Benefits**

- Warnings stop if the driver switches on the turn signal, which prevents the system from providing alerts every time the driver intends to change lanes.[5]
- Braitman et al. found that 54-64% of drivers with lane departure warnings used their turning signals more often and 67-71% reported less drifting from lane to lane.[6]
- A study by the Insurance Institute for Highway Safety analyzed crash data from 2004-2008 and found that lane departure warning systems could have prevented 4-6% of single-vehicle collisions, 23-27% of head-on collisions, 24-29% of sideswipe same direction collisions, and 22-25% of sideswipe opposite direction collisions.[4]
- Kusano et al. analyzed single-vehicle crash data from 2012 and found that lane departure warning systems could have prevented between 11 and 23% of drift-out-of-lane crashes and 13% and 22% of seriously to fatally injured drivers.[7]

Safety **Risks**

- Some systems only operate over limited speed ranges. Most operate at speeds over 60 km/h.[5] Therefore; some vehicles travelling at less than 60 km/h will not be warned of lane departures.[4]
- Systems may be late in warning drivers of lane departures if they are speeding.[4]
- A lane departure warning system does not take control of the vehicle or prevent the vehicle from continuing to move into the other lane.[4]
- These systems do not work if lane markings are not visible (e.g. covered by snow) or on curved roads.[4]
- A Status Report by the Insurance Institute for Highway Safety reported that only 51% of the 983 vehicles they observed had their lane maintenance systems turned on.[8]
- A Status Report by the Insurance Institute for Highway Safety found that drivers turned off their lane maintenance systems nearly half of the time due to annoyance (e.g., frequent danger alerts from the system without apparent danger).[8]
- The system must be activated each time the vehicle is started and a study by Braitman et al., shows that many drivers were unaware they even had it.[6]

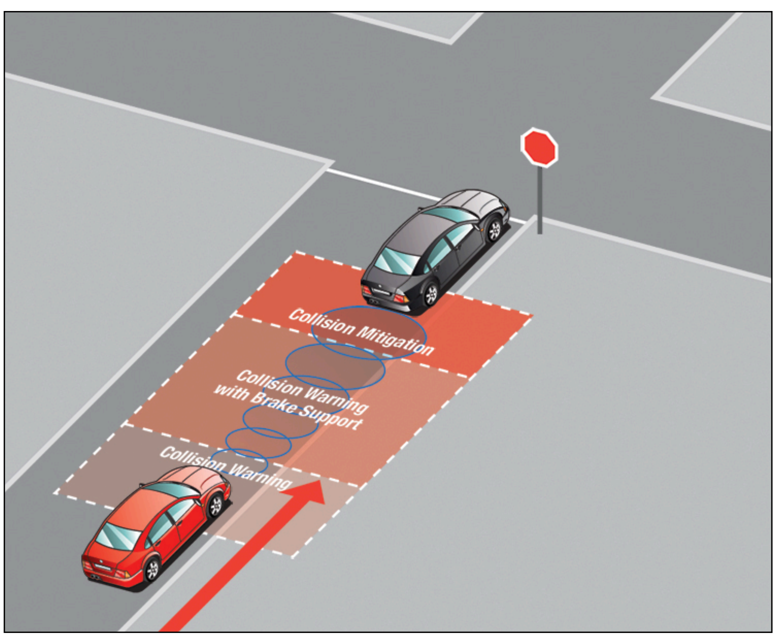
Summary

Lane departure warning systems have the potential to prevent a large percentage of collisions and are similar to other existing environment-based technology (e.g., raised or grooved rumble strips along lane boundaries). However, systems that deliver warnings earlier and operate at lower speeds may prevent far more crashes and injuries than systems that warn late and operate only at high speeds.[7] Also, a reluctance to use the technology may limit its potential effectiveness. The following points should be considered to enhance the effectiveness of LDW systems:

- Warning systems are more likely to be turned on if they have tactile warnings (e.g., seat vibrations) (54 percent) instead of auditory warnings (e.g., beeping) (46 percent).[8]
- Lane departure prevention systems, which guide the vehicle back into the lane when it begins to drift, also were more likely to be turned on than lane departure warning systems.[8]
- Systems with more complex deactivation process (e.g., navigating a menu, with several steps) have a much higher than average observed use rate (e.g., 86 %)[8]
- Future lane departure warning evaluation should prioritize early warnings and full-speed range operation.[7]

Forward Collision Warning and Braking Systems

Forward collision warning systems monitor the speed and distance from the vehicle in front of the driver. It uses this information to detect when the vehicle ahead slows down



Source: Transport Canada, Forward Collision Warning and Braking, 2013.

or stops and alerts the driver when they are getting too close. Some systems will also apply brake support, activate seat belt pre-tensioners and pre-charge the airbag systems if the driver does not react to the warning.[9]

TABLE 2: Forward Collision Warning and Braking

Safety **Benefits**	Safety **Risks**
❖ Braitman et al. found that approximately 50% of the drivers followed vehicles ahead less closely when using forward collision warning systems.[6] ❖ The Insurance Institute for Highway Safety found that 61-70% of front-to-rear collisions in 2004-2008 could have been prevented with the use of forward collision warning systems.[4] ❖ Forward collision warning systems that are able to detect pedestrians, cyclists and roadside objects have the potential to reduce single-vehicle collisions by 17-18%.[4] ❖ A study conducted by the Insurance Institute for Highway Safety found that all but one vehicle had its forward collision warning systems on, indicating that user annoyance was not an issue and overall usage rates were high.[8]	❖ The original braking system in the vehicle must be well maintained in order for the brake assist system to function at the optimal level.[9] ❖ Some systems can only prevent crashes at speeds up to 30 km/h because they are designed to operate in stop-and-go traffic.[9] ❖ Generally, the system warning distance is above 40km/h and varies by vehicle make or model.[9] However, the warning distance can usually be altered by the driver which can have dangerous implications for drivers who are unaware of safe stopping distances. ❖ The effectiveness of systems that use cameras to detect other vehicles is compromised during weather conditions such as rain, snow or fog and in varying lighting conditions, such as, strong sunlight or darkness.[9] ❖ Systems that use radar sensors may be unable to detect other vehicles on curved roads.[9] ❖ System warnings may not occur if the distance from the vehicle ahead is very small.[9] ❖ Braitman et al. found a small proportion of drivers (5%) with forward collision warning systems look away from the road more often or follow the vehicle ahead more closely (2%).[6] ❖ Most current systems use radar or LIDAR (Light Detection and Ranging) sensors to monitor the area in front of the vehicle and can therefore only determine distances from objects with reflective surfaces.[4]

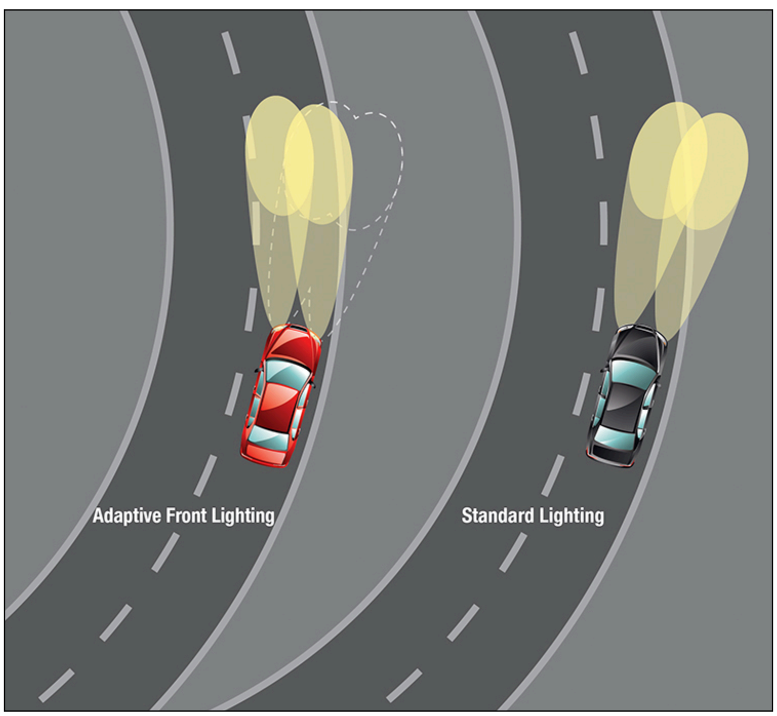
This system has the potential to prevent rear end collisions. Some newer models are also able to detect pedestrians, cyclists and roadside objects and notify drivers of their presence, which can further decrease the likelihood of collisions and fatalities.[4]

Summary

Of the collision avoidance systems reviewed in this case study, forward collision warning systems have the most potential for success. Research from the US shows this technology could potentially prevent 2.3 million crashes (e.g., angle, rear end and single vehicle) each year,* including 210,000 serious injuries and 7,166 fatalities. However, much like lane departure warning technology, systems that deliver warnings earlier and operate at lower speeds may prevent far more crashes and future evaluation of collision avoidance systems should prioritize early warnings and full-speed range operation.[7]

Advanced Forward Lighting Systems

Advanced forward lighting systems automatically adjust the vehicles lighting to accommodate for changing driving conditions (e.g., visibility). Some systems can



Source: Transport Canada, Advanced Forward Lighting Systems, 2013.

* May actually be 3.7 million, considering approximately half of all front-to-rear crashes are not reported to police.

automatically switch from high beams to low beams when another vehicle approaches and swivel the main beams left and right up to 15 degrees according to the curve of the road. Other systems can also shine light 90 degrees in either direction when the vehicle is turning at an intersection.[10]

TABLE 3: Advanced Forward Lighting Systems

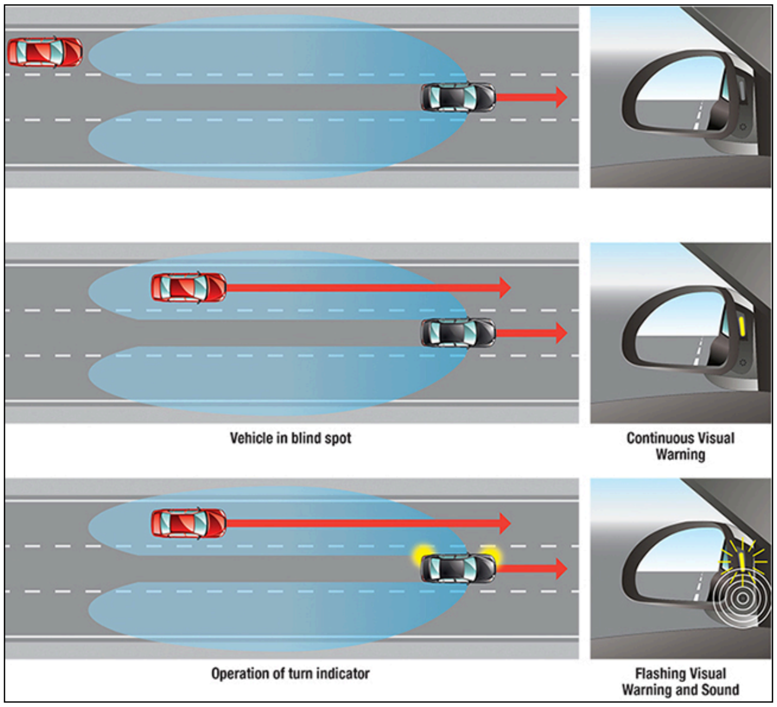
Safety **Benefits**	Safety **Risks**
❖ The Insurance Institute for Highway Safety found that advanced forward lighting could have prevented 4% of front-to-rear, single-vehicle, and sideswipe same direction collisions that occurred on curves in darkness or twilight from 2004-2008.[4] ❖ Adaptive headlights have been reported to increase visibility of pedestrians on dark curves by 14 percent.[11]	❖ Most systems require the driver to manually turn on the system (by turning the light switch to the automatic setting).[10] ❖ Braitman et al. found that 18% of drivers with advanced forward lighting had a greater willingness to drive faster.[6] ❖ Braitman et al. found that 40% of drivers with advanced forward lighting were more willing to drive at night, which is potentially less safe than driving during the day.[6]

Summary

Advanced forward lighting systems appear to have more safety risks than benefits. Although this system can improve lighting conditions, the increased willingness to drive faster, and at night, can have negative implications on road safety. This has been an issue with other visibility enhancements (e.g., reflector posts, raised pavement markers, and other roadway markings on curves), as some drivers increase their speed with improved visibility.[11] Future advanced forward lighting systems can mitigate this risk by partnering with speed monitoring systems to prevent users from driving above the speed limit.

Blind Spot Detection Systems

Blind spot detection systems use cameras or radar sensors to monitor the sides and rear of a vehicle and warn drivers of other vehicles in their blind spots. Blind spots include areas around the vehicle (the sides and the rear) that are out of the driver's line of sight. Warning signals usually alert drivers using lights that are mounted on the rear view mirrors, side view mirrors or doors. If the driver intends to change lanes and switches on their turn signal the system will scan all blind spots and notify drivers of any vehicles present by using red or yellow flashing symbols or auditory tones.[12] This system has the potential to prevent collisions caused by drivers intentionally changing lanes without full awareness of what is in their blind spot.[4]



Source: Transport Canada, Blind Spot Detection, 2013.

TABLE 4: Blind Spot Detection

Safety **Benefits**	Safety **Risks**
❖ A study by the Insurance Institute for Highway Safety analyzed crash records from 2004-2008 and found that 24% of lane changing collisions could have been prevented with the use of blind spot detection systems.[4]	❖ Blind spot detection systems may be unreliable in inclement weather (e.g. rain, snow, fog).[4] ❖ The system relies on drivers to check their side mirrors for the warnings. As a result, experts are concerned that drivers who do not use their side mirrors will miss the warning signals.[13]

Summary

Although blind spot detection systems have the potential to prevent a portion of lane-changing crashes, it is worth noting these crashes (e.g., angle, front-to-rear, and sideswipe same direction) are not usually serious and/or fatal (as they involve a vehicle approaching from behind). Also, if drivers are failing to use their side mirrors in the first place, the addition of warning alerts will do little to impact their behaviour.[11]

Limitations of the Data

Research regarding collision avoidance systems provides important information on their effectiveness and contribution to road safety; however, certain limitations should be kept in mind:

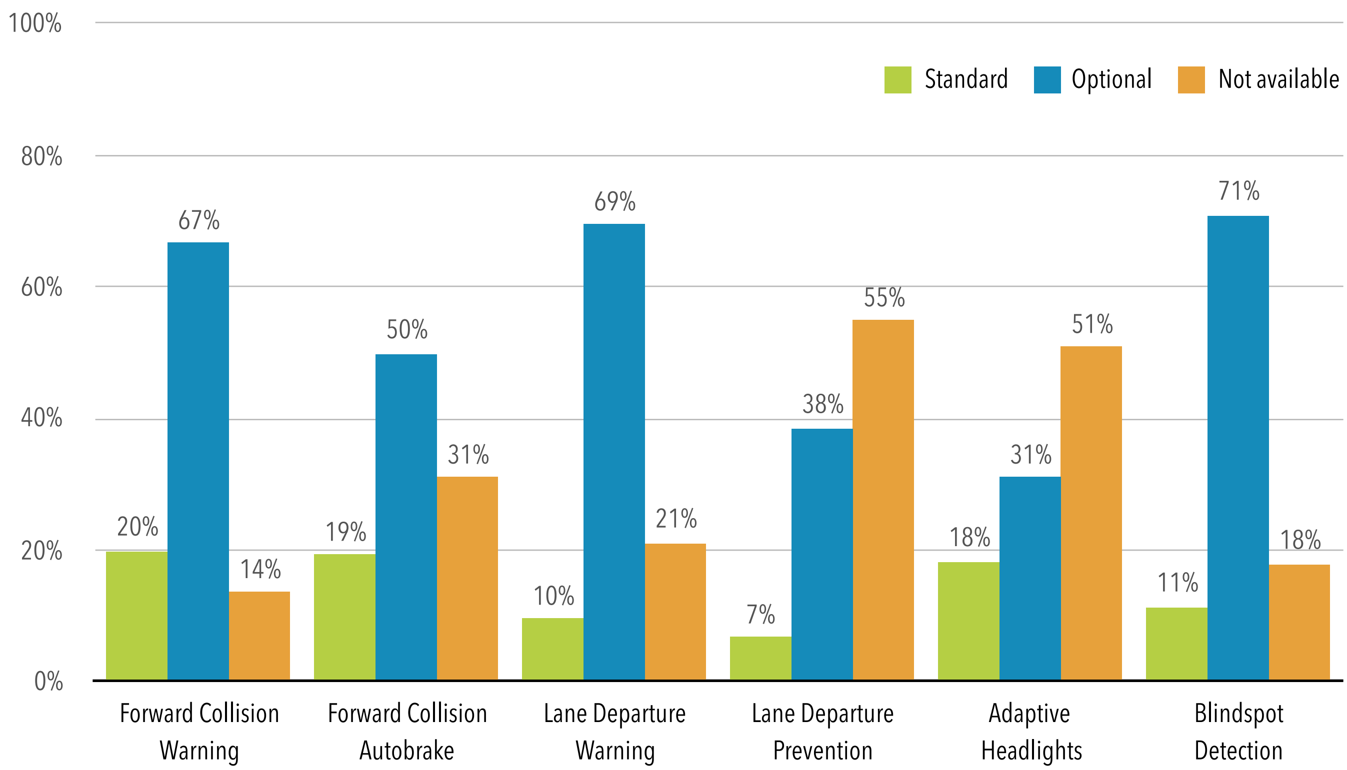
- **A focus on luxury vehicles**: Many studies measuring the effectiveness of collision avoidance systems solely examine luxury brand cars and it is not clear how effectively these systems would operate in non-luxury brands.[4]
- **Difficulty assessing individual systems**: Certain vehicles contain multiple collision avoidance systems, which makes it difficult to assess the effectiveness of isolated/individual systems.[3]
- **Lack of real world experience**: Many studies attempt to estimate the number of collisions that can be prevented using collision avoidance systems. However, these projections assume proper system function and driver compliance. If these projections considered factors such as driver annoyance, distraction and/or impairment, then the estimated number of collisions prevented would be much lower.[4]
- **Rapid change in technology**: The current research is limited by the rapidly changing technology in crash avoidance systems. By the time the research is published the limitations listed in the research paper may already be addressed in newer versions of the system.[4]

Availability

According to the Insurance Institute for Highway Safety the six most common collision avoidance systems available in vehicles are: forward collision warning, forward collision autobrake, lane departure warning, lane departure prevention, adaptive headlights and blind spot detection.[14] There are currently 671 vehicles (2017 models) that feature one or more of these systems.

The following graph depicts the prevalence of each system in the 671 2017 model vehicles that offer these features:

FIGURE 1: Collision Avoidance Systems in 2017 Vehicles



Based on the Insurance Institute for Highway Safety "Crash avoidance features by make and model" data.

Findings

- Most collision avoidance systems are offered as optional features in vehicles.
- Forward collision warning, forward collision autobrake and adaptive headlights are most likely to come standard with vehicle purchase.
- Lane departure prevention is least likely to be offered.

For a detailed list of collision avoidance systems by make and model visit: http://www.iihs.org/iihs/ratings/crash-avoidance-features

What's Next?

Vehicle-to-vehicle (V2V) Communications

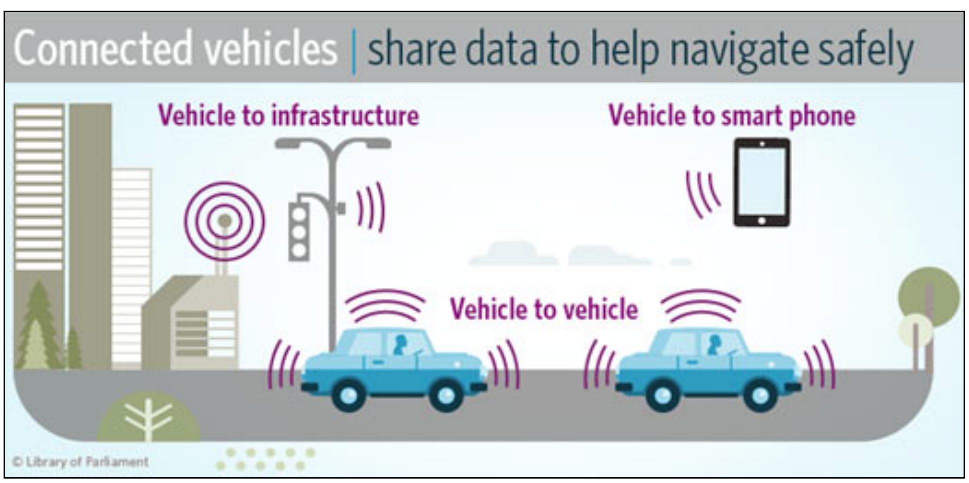
Vehicle-to-vehicle communications allow vehicles to transmit information regarding their actions to other vehicles.[15] For example, if the lead vehicle in a long chain of vehicles has to break suddenly, this message will be transmitted to the vehicles behind it. Drivers will be alerted of this action and in some cases the vehicle will begin braking automatically.[15]

Vehicle-to-infrastructure (V2I) Communications

Vehicle-to-infrastructure (V2I) communications allow vehicles to receive and transmit information to road infrastructure.[15] For example, road systems can alert drivers when their vehicle is approaching a red light, so that drivers can prepare to stop.[15]

Vehicle-to-smartphone Communications

Vehicle-to-smartphone communications allow smartphones to monitor certain aspects of the vehicle (e.g. airbag triggers) and use this information to detect if a collision occurs. In the event of a collision the smartphone would relay the message to others through email or SMS and immediately notify emergency responders.[16]



Source: Library of Parliament, Automated and Connected Vehicles: Status of the Technology and Key Policy Issues for Canadian Governments

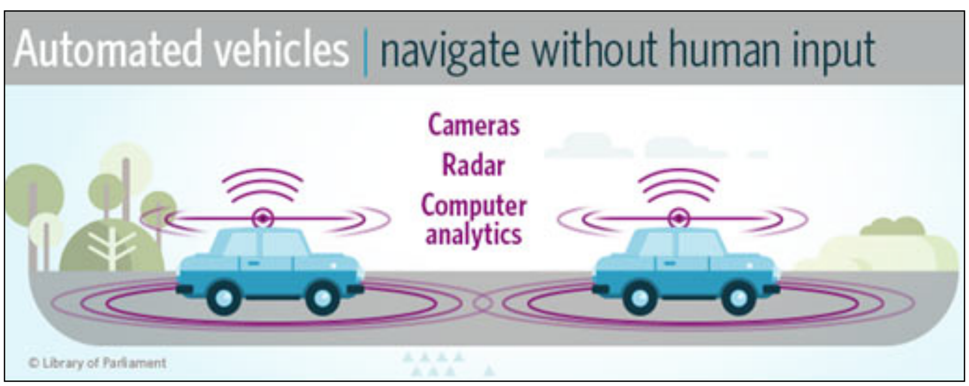
Safety Benefits – A pilot study in Ann Arbor, Michigan in 2013 tested the functionality and reliability of the V2V and V2I communication systems and results found that the systems were technically feasible and effective in reducing property damage and injury crashes.[15]

Issues – There are concerns about the privacy/security of users and the technical and performance requirements of the systems.[15]

Autonomous Vehicles

Autonomous vehicles use technology to detect surroundings and travel on roads without any assistance from human drivers. Some experts estimate that autonomous vehicles will be commercially available by 2020.[17] However, there is uncertainty regarding uptake by consumers.

Experts expect a large transition period between the initial release of autonomous vehicles and high levels of use on the roads due to the high costs of the vehicles.[17] As a result, it is estimated that autonomous vehicles will not be the prevailing mode of transportation until the 2040s and 2060s, when the technology becomes more common and affordable.[17]



Source: Library of Parliament, Automated and Connected Vehicles: Status of the Technology and Key Policy Issues for Canadian Governments, 2016

Conclusion

Over the past 40 years, Canada has seen a 60% reduction in road fatalities, despite a doubling in population.[18] A large portion of this reduction can be attributed to the significant changes that have been made in vehicle engineering.[18] Yet, despite these incredible improvements, one person still dies every four hours or is admitted to hospital every 90 minutes as a result of a traffic collision.[18] Through the advancement of in-vehicle technologies we can continue to move towards our goal of zero fatalities and injuries on Canadian roads. Current collision avoidance systems have their disadvantages, but are a step in the right direction. One important factor that must be kept in mind is user compliance. If the technology results in user annoyance or is unsuccessful in warning drivers, the effectiveness of the system is compromised. This was particularly evident in evaluations of lane departure warnings and blind spot detection systems. If this issue can be addressed, further development of collision avoidance systems should be encouraged and combined with regulation and consumer education.[18]

Summary

- Four of the most common collision avoidance systems currently on the market are: lane departure warnings, forward collision warning and braking, advanced forward lighting, and blind spot detection.
- It is estimated that the collective implementation of all four systems could prevent or mitigate up to 1,866,000 collisions each year.
- Of the four technologies, forward collision warning systems have the greatest potential for reducing collisions.
- The effectiveness of each system is compromised on curved roads, during weather conditions such as rain, snow or fog and in varying lighting conditions, such as, strong sunlight or darkness.
- User compliance is an issue with lane departure warnings and blind spot detection systems.
- Limitations of research on collision avoidance systems include: a focus on luxury vehicles, difficulty assessing individual systems, a lack of real world experience and rapid change in technology
- All four collision avoidance systems are mostly optional additions to the 671 vehicles (2017 models) that offer collision avoidance technologies.
- Vehicle-to-vehicle (V2V) communications, vehicle-to-infrastructure (V2I) communications and autonomous vehicles are the next phase of collision avoidance technologies.

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